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REPEATABILITY OF THE NEAR POINT OF CONVERGENCE MEASUREMENT WITH THE OBJECT AND THE FILTER METHODS

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Els Srs. Carles Otero i Jaume Pujol, com a tutor i director del treball,

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Que el Sra. Ana Muñoz García ha realitzat sota la seva supervisió el treball: Repeatability of the near point of convergence measurement with the object and the filter methods, que es recull en aquesta memòria per optar al títol de grau en Òptica i Optometria.

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Terrassa, 12 de juny de 2017

GRAU EN OPTICA I OPTOMETRIA

REPEATABILITY OF THE NEAR POINT OF CONVERGENCE MEASUREMENT WITH THE OBJECT AND THE FILTER METHODS

RESUM

ABSTRACT

The purpose of this study is to determine the repeatability of Near Point of Convergence break point measured using the object and the red filter methods.
To this end, in two separated sessions, NPC was measured in 10 young and healthy adults using both methods. The same examiner, maintaining the same cabinet and environmental conditions, obtained sets of measurements. Finally, the Wilcoxon test and Bland and Altman method estimated the repeatability of the tests measurements.
When agreement between the two tests was assessed, it was found that the NPC break points were higher when determined using the red filter method (median break point 10 cm in session 1 and 10,25 cm in session 2) than determined using the object method (median 6,5 cm in session 1 and 6 cm in session 2). In clinical terms, according to the expected values of NPC break point, there were no significant differences between sessions in both methods employed (Significance: Object method p=0,611, red filter method p=0,078). In addition, the intraexaminer within subject reliability was found to be fair in both tests.
In conclusion, the object and the filter methods used to measure the NPC showed fairly good repeatability for measuring the break point.

RESUMEN

El objetivo del estudio es determinar la reproducibilidad del punto de ruptura del punto próximo de convergencia medido con el método del objeto y el del filtro rojo.
Con esta finalidad, en dos sesiones separadas, el PPC fue medido en 10 adultos jóvenes y sanos utilizando ambos métodos. El mismo examinador, manteniendo el gabinete y las condiciones ambientales, fue el que obtuvo los diferentes grupos de medidas. Finalmente, el test Wilcoxon y el método Bland and Altman estimaron la reproducibilidad de las medidas encontradas.
Cuando se estudió la concordancia entre las dos pruebas, se encontró que los puntos de ruptura del PPC resultaban más altos cuanto eran determinados por el método del filtro rojo (punto de ruptura mediano 10 cm en sesión 1 y 10,25 cm en sesión 2) que determinado por el método del objeto (punto de ruptura mediano 6,5 cm en sesión 1 y 6 cm en sesión 2). En términos clínicos, según los valores esperados para el punto de ruptura del PPC, no hubo diferencias significativas entre las sesiones en los dos métodos empleados (Significancia: método del objeto p=0,611, método del filtro rojo p=0,078). Además, la fiabilidad intrasujeto resultó ser buena en ambas pruebas.
En conclusión, tanto el método del objeto como el método del filtro rojo utilizados para medir el PPC, mostraron buena reproducibilidad para medir el punto de ruptura.

RESUM

L'objectiu del estudi és determinar la repetibilitat del punt de ruptura del punt pròxim de convergència mesurat amb el mètode de l'objecte i el del filtre vermell.
Amb aquesta finalitat, en dues sessions separades, el PPC va ser mesurat en 10 adults joves i sans utilitzant ambdós mètodes. El mateix examinador, mantenint constants el gabinet i les condicions ambientals, va ser el que va obtenir els diferents grups de mesures. Finalment, el test Wilcoxon y el mètode Bland and Altman van estimar la repetibilitat de les mesures trobades.
Quan es va estudiar la concordança entre les dues proves, es va trobar que els punts de ruptura del PPC resultaven més alts quan eren determinats pel mètode del filtre vermell (punt de ruptura medià 10 cm en sessió 1 i 10,25 cm en sessió 2) que determinats pel mètode de l'objecte (punt de ruptura medià 6,5 cm en sessió 1 i 6 cm en sessió 2). En termes clínics, segons els valors esperats per al punt de ruptura del PPC, no va haver-hi diferències significatives entre les sessions en els dos mètodes emprats (Significança: mètode de l'objecte p=0,611, mètode del filtre vermell p=0,078). A més, la fiabilitat intrasubjecte va resultar ser bona en ambdues proves.
En conclusió, tant el mètode de l'objecte com el mètode del filtre vermell utilitzats per mesurar el PPC, van mostrar bona repetibilitat per mesurar el punt de ruptura.

Repeatability of the near point of convergence measurement with the object and the filter methods

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Abstract

Purpose: To determine the repeatability of Near Point of convergence break point measured using the object and the red filter methods.

Methods: In two separated sessions, NPC was measured in 10 young and healthy adults (mean age 22,7, SD 2,79 years) using the object and the red filter methods. The same examiner, maintaining the same cabinet and environmental conditions, obtained sets of measurements. The Wilcoxon test and Bland and Altman method estimated the repeatability of the tests measurements.

Results: When agreement between the two tests was assessed, it was found that the NPC break points were higher when determined using the red filter method (median break point 10 cm in session 1 and 10,25 cm in session 2) than determined using the object method (median 6,5 cm in session 1 and 6 cm in session 2). In clinical terms, according to the expected values of NPC break point, there were no significant differences between sessions in both methods employed (Significance: Object method p=0,611, red filter method p=0,078). In addition, the intraexaminer within subject reliability was found to be fair in both methods.

Conclusions: The two methods used to measure NPC showed fairly good repeatability for measuring the break point.

Keywords: Binocular vision, Near point of convergence, Break point, Red filter method and object method.

1. Introduction

Binocular vision is the coordination and integration of the information received from the two eyes separately into a single binocular percept [1]. The study of this condition considers the analysis of the vergence system and its relationship with accommodation. Vergence movements (convergence and divergence) are disjunctive eye movements whose main objective is to align both eyes' fovea with

targets located at different distances from the observer. They are used to track objects moving in depth and to maintain a fused and single perception [2].

The examination of binocular vision is important to find possible visual dysfunctions that justify the symptomatology of patients, such as headache, blurred vision, eye ache and double vision, and develop a treatment plan. These visual dysfunctions might interfere with subject's work performance or the learning process in childhood. Several studies have indicated that children with reading and learning problems show a higher incidence of hyperopia and binocular vision disorders such as exophoria at near or vertical phoria than normal readers [3]. In fact, those people who spend more time on close vision, reading or using electronic devices, are more likely to demonstrate symptoms and signs related to accommodative or vergence anomalies [4].

A variety of optometric tests typically used in current clinical practice are based on vergence eye movements. This study is focused on Near Point of Convergence (NPC), although the positive and negative fusional vergence and vergence facility are also explained due to their clinical relevance.

The NPC is the nearest point in space where an individual can maintain binocular fusion[5]. A small stimulus of approximately 20/30 visual acuity is used to measure the NPC. The test consists in moving the stimulus along the patient's midline gradually from 40 centimetres toward the subject's bridge of the nose. The patient is instructed to keep the target single during the test and report when it appears double. The distance from the target at this position to the patient is denominated the break point and it actually corresponds to the measured value of NPC. Then, the target is slowly moved away and the patient has to notify when the stimulus appears simple again. The point where the fusion is retrieved is denominated the recovery point. Those distances are typically measured with a rule.

In some cases, the patient is not aware of double vision even if one eye loses fixation. That is why it is important that the optometrist watches the patient's eyes and determines if one of the eyes loses fixation and turns out. Then, the NPC is determined objectively since it does not require the answer of the patient. The eye that maintains fixation is generally considered to be the dominant eye.

The normal values of the NPC are less than10 cm for break point and less than 15 for recovery point. A break distance farther away than 10 cm is defective or remote [6].

The NPC can also be tested with an object, a penlight alone and a penlight with a red filter in front of one eye. Some studies[7] claimed that in cases in which a convergence insufficiency is suspected but the NPC with a penlight alone is normal,

the red filter method may give a NPC more remote and demonstrate better correlation with fusional vergences. Other studies[8] concluded that targets with a high accommodative demand result in a nearer NPC due to the increased accommodative convergence. Many researchers consider that the NPC is the most important diagnostic parameter in convergence insufficiency[5]. In addition, it helps to control the improvements achieved after treatment[8].

The NPC's repeatability is influenced by patient's voluntary convergence, the accommodative convergence, the visual acuity and the stimulus type. Some of these variables are difficult to be controlled, so they can influence negatively on the test's repeatability[8].

Fusional vergences represent the ability to converge and diverge maintaining the focal plane immobile and the simple vision. The range of fusional vergences provides information about the ability to maintain binocular vision. To examine the *positive fusional vergence,* a base-out prism bar is slowly increased and the patient is instructed to keep the target single and clear and to report when the target becomes blurred and then, when it becomes double [9]. Then the prism is slowly reduced until fusion is regained. Similarly, a base-in prism bar is used to examine the *negative fusional vergence*.

Fusional vergences can also be examined with rotary prisms in the phoropter. The fusional vergence amplitude using the rotary prisms method is measured through a soft and progressive increment of prismatic power on comparison with the prism bar method, which is based on small prismatic power leaps.

For vertical vergences analysis, right eye's supravergence is examined first with base-down prism and infravergence with base-up prism. Then, the same process is repeated for the left eye. This procedure is only required when a vertical heterophoria exists.

The target used in this test consists in a vertical (for horizontal vergences) or horizontal (for vertical vergences) line of letters with a 20/30 visual acuity. Fusional vergences are typically examined both at near distance (40 cm) and at far distance (6 m)[9].

The expected values of fusional vergences are shown in Table 1.

	Distance fixation (6m)	Near fixation (40cm)
Lateral fusional vergences	NFV: ΔBI X/7/4 (±2) PFV: ΔBO 9/19/10 (±5)	NFV: ΔBI 13/21/13 (±5) PFV: ΔBO 17/21/11 (±5)
Vertical fusional vergences	ΔBU and ΔBD 4/2 (±1)	ΔBU and ΔBD 4/2 (±1)

Table 1. Normal values of fusional vergences according to Morgan's studies[10].

The fusional vergence ranges are affected by the order of the application of convergence and divergence measurements[8]. In general, when the fusional vergence measurements are repeated in the same patient, the second value differs from the initial. Sheedy[11] stated that "a difference of 10 prism diopters from one fusional vergence amplitude measurement to another is not unusual unless rigorous controls are applied."

The measurement of fusional vergence is fairy reliable for determining negative fusional vergence, although positive fusional vergence measurements show low repeatability[8].

The Vergence facility is the ability of the fusional vergence system to respond as fast as possible and precisely to changing vergence demands over time. Clinically, it is defined as the number of cycles per minute (cpm) that a stimulus can be fused through alternating 3 Δ base-in and 12 Δ base-out prisms [12]. This test is typically performed at both far distance (6m) and at near (40 cm). The expected value is ≥9 cpm at distance and ≥13 cpm at near [9].

When the results of the tests explained above are abnormal, patients might have a binocular vision dysfunction. In 1896, Duane[13] suggested a method of classification for strabismic binocular dysfunctions based on the distance where the deviation was greater. Currently, this classification is also applied to nonstrabismic binocular dysfunctions [1].

Convergence excess consists in a high esophoria at near and orthophoria at distance. It is also accompanied by low negative fusional vergence and, in some cases, high positive fusional vergence. Vergence facility is usually low with difficulty with base-in prisms and NPC might be close to the nose root [14]. Convergence excess patients should be carefully instructed about the importance of visual hygiene. Convergence excess has a prevalence of about 1,5%[15].

Patients with *Convergence insufficiency* are orthophoric or slightly exophoric at distance and exhibit a higher near exophoria. It is often associated with symptoms such as double vision, eyestrain, headaches, blurred vision, and loss of place while reading or performing near work[16]. Convergence insufficiency is typically characterized by a remote near point of convergence, a decreased positive fusional convergence at near and a decreased vergence facility with base-out difficulty. It is important to differentiate this condition from other visual anomalies such as *Accommodation insufficiency* or convergence paralysis[14]. It is themost prevalent nonstrabismic binocular dysfunctions. Its prevalence is reported to range from 1 to 33%[17].

D*ivergence excess* is characterized by a decompensated exophoria (usually more than 15 Δ) at distance and an orthophoria or a reduced exophoria at near. In this case, patients might refer diplopia at distance although they commonly suppress an image in order to avoid symptomatology. This condition is associated with decreased positive fusional vergence and vergence facility with base-out difficulty at distance. Approximately 50% of vertical deviations are associated with divergence excess [14].

On *Divergence insufficiency* dysfunction, patients present a high decompensate esophoria at distance and orthophoria at near. As the convergence insufficiency, divergence insufficiency can also be confused with divergence paralysis. This condition is typically characterized by decreased negative fusional convergence and a decreased vergence facility with base-in difficulty at distance.

The binocular dysfunctions can be combined with each other. *Basic esophoria* refers to convergence excess together with divergence insufficiency, which has a prevalence of about 1,5%[15]. Similarly, *basic exophoria* consists in convergence insufficiency combined with divergence excess. This condition is more prevalent than basic esophoria, which is presented in a 3,1% of cases[15].

The objective of the present study is to analyse the repeatability of the break point of the NPC with the object and the red filter methods. This analysis will be used to know and validate the optometric tests typically used to evaluate binocular vision and, subsequently in future studies, assess the agreement between those methods and a novel 3D system based on virtual reality called Eye and Vision Analyzer (EVA, Davalor Salud, Spain).

2. Methods

Subjects.
A group of 10 subjects participated in the study. The mean age ± SD (standard deviation) was 22,7 ± 2,79 years (range from 18 to 30 years). All subjects had 20/20 visual acuity in both eyes (distance and near) with their best correction. Patients with strabismus, accommodative dysfunctions or any ocular pathology were excluded.

Procedure.
To measure the NPC through the object method, a pen was moved along the subject's midline. The pen was moved gradually from 40 cm toward the bridge of the nose of the subject at a rate of approximately 3–5 cm/s. The subjects were instructed to keep the tip of the pen single during the test and report when it appeared double (break point). The distance between break point to the plane of the lateral canthus was measured with a millimetre ruler.

To measure the NPC through the red filter method, a red filter was positioned in front of the left eye of the subjects. A penlight was moved gradually from 40 cm toward the bridge of the nose of the subject at a rate of approximately 3–5 cm/s. The subjects were instructed to keep the light single during the test and report when it appeared double (break point). The distance between break point to the plane of the lateral canthus was measured with a millimetre ruler.

The subjective break point values were measured and recorded in centimetres. If there was no subjective report of diplopia, the point at which the patient objectively lost ocular alignment was recorded as the break point. Patients wore their habitual correction during testing. Both methods were performed twice. The time between the first and the second measures was at least 24 hours.

Statistical analysis.
A statistical analysis of the results was performed using the software SPSS Statistics version 22.0 (IBM Corp., USA) for Windows and the Microsoft Office Excel 2011 (Microsoft Corp., USA). In all cases a p-value less than 0.05 was considered to be statistically significant.
First, the 10 values obtained for each patient in two different sessions were analyzed with the Shapiro-Wilk test for both methods. This test shows whether there is a normal distribution of data in each of the sets analyzed ($p>0.05$).
After that, the comparison between the measurements in both sessions was analyzed applying the non-parametric Wilcoxon signed-rank test (when there was not a normal distribution) and Bland and Altman plots.

3. Results

Descriptive data (median, IQR) for all variables computed from the NPC break point acquired with the object and red filter method in two different sessions are shown in Table 2. As expected, the values of NPC are higher with the red filter method.

Parameters	Median	IQR = Q3 –Q1
NPC Object 1	6,500	4,000
NPC Object 2	6,000	2,625
NPC Red Filter 1	10,000	5,75
NPC Red Filter 2	10,250	6,125

Table 2. Descriptive statistics table.

Then, by means of the Shapiro-Wilk test, we obtained that all data were abnormally distributed ($p<0.05$) and consequently, a non-parametric test (Wilcoxon signed-rank test) was used to determine whether there were statistically significant differences between the values provided by both sessions in each method. The Table 3 shows the results obtained in this case. As it can be seen, for the two methods no significant differences between sessions were found ($p>0,05$).

Parameters	NPC Obj1 - NPC Obj 2	NPC RF 1- NPC RF 2
Z	-0,509	-1,761
Sig.	0,611	0,078

Table 3. Wilcoxon Test results.

Later, the intraexaminer standard deviation within subject, shown in Table 3, was calculated in order to analyse the agreement and precision of the two methods. It can be seen that this mean difference is not clinically significant in terms of NPC (centimetres) since it is under 1.18 (object method) and 0.9 (red filter method), which is approximated to the limit of significance in clinical terms (0,50-1,0 centimetres depending on the professional).

Parameters	NPC Object	NPC Red Filter
SD within subject	1,1779219	0.89442719

Table 3. Intraexaminer standard deviation within subject.

Finally, the Figure 1 shows the Bland and Altman plots, which analyse the difference versus mean plots of repeatability for the NPC measurements with both methods. The mid line represents the averaged difference (MD) of the measurements from final session and initial session. The up and down dashed lines indicate the lower and upper 95% limits of agreement (MD ± 1,27 for object method and MD ± 0,82 for red filter method).

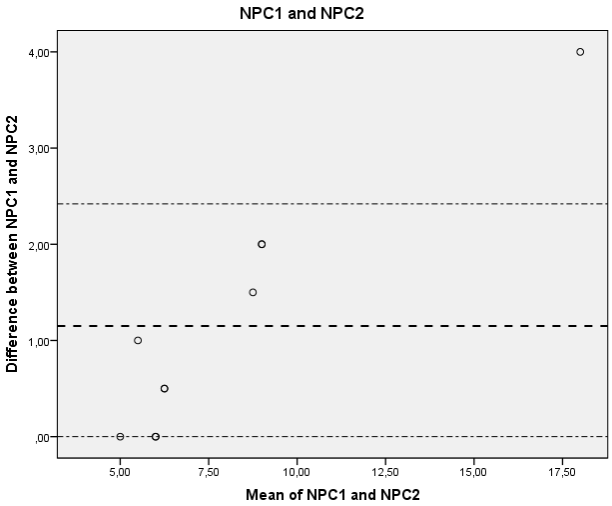

Figure 1.1 Bland and Altman plots showing the mean of the differences and the corresponding 95% Limits of Agreement between the values provided by the NPC measures with the object method.

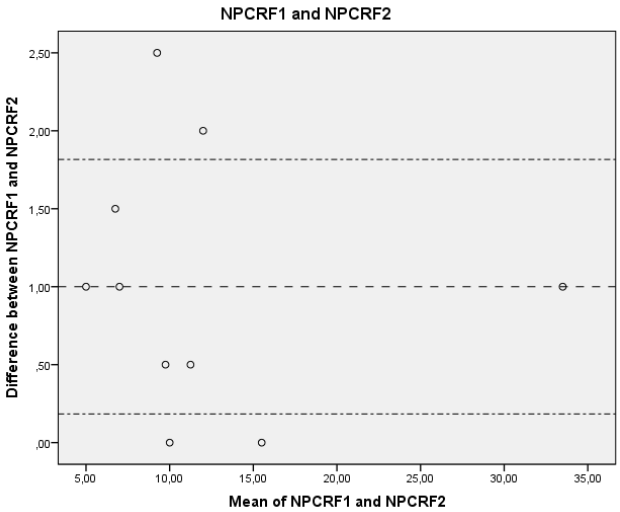

Figure 1.2 Bland and Altman plots showing the mean of the differences and the corresponding 95% Limits of Agreement between the values provided by the NPC measures with the red filter method.

4. Discussion

In the present study, we studied the repeatability of the Near point of convergence break point using the object and the red filter method.

Rouse et al[18] examined the repeatability of NPC break point and found a repeatability's coefficient larger (examiner 1 ± 5,33cm, examiner 2: ± 5,00) than the found in our study (± 1,27 for object method and ± 0,82 for red filter method).

In the same manner Beatriz Antona[8], in 2010, examined the repeatability of NPC break and recovery point and the results showed that medium difference between sessions were statistical and clinically insignificant (MD: 0,13 cm for break point and 0,03 cm for recovery point). As it can be seen in our analysis and according to Beatriz Antona's studies, the break point of the NPC is very repeatable. However, the NPC's repeatability is influenced by many external conditions such as patient's voluntary convergence, the accommodative convergence, the visual acuity and the stimulus type. Some of these variables are difficult to be controlled, so they can influence negatively on the test's repeatability.

As we expected, the NPC break point measured with the red filter method gives more remote results than the object method, because this test offers a slight obstacle to fusion and minimizes the effect of voluntary convergence[6].

The intraexaminer within subject reliability was found to be fair in both methods. However, the standard deviation was higher on the object method than the red filter one.

5. Conclusion

NPC is the most important diagnostic parameter in convergence insufficiency and helps to control the improvements achieved after treatment. For this reason, it is important to know the reliability and precision of the different methods employed.

According to our study, NPC break point measured by the object and the red filter method is fairly reliable and repeatable as long as it remains within constant environmental conditions, examiner and material inter alia.

These findings are not unexpected and the clinician in practice should know that is important that the method selected for the initial evaluation is also used for all future measurements.

6. Ethical and social commitment

According to its normative, in the final degree's project has to feature a section that makes reference to the transversal competition of ethical and social commitment. Therefore, at this point the work is analyzed since an ethical point of view and does reference to the social and legal implications that comports the study.

To begin with, it is necessary to highlight that the main aim of this work is to do a study to know the repeatability of the break point of the near point of convergence measured with the object and the filter methods. The research and the knowledge in the health sciences field has a direct repercussion in the improvement of the population visual health and, therefore, in their quality of life.

Regarding the legal aspects it is necessary to treat two fundamental aspects. In the first place, it has been not considered necessary to sign an informed consent for the participants in the measures of the next point of convergence with both methods because they all were participants of the own work. On the other hand, the second legal aspect that has taken into account makes reference to the security measures that are always necessary to take. At the time of doing the measures, the voluntary patients security has been taken to ensure. In no case, material that could cause annoyances or damages to their ocular structures has been used.

7. References

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